Track Preference: **New Ideas?** Systems Engineering

Presentation Title: Systems Engineering & Integration for Technology Programs

Synopsis:
This presentation will provide an overview of a systems engineering and integration approach for technology development programs that have multiple research and technology projects in their portfolio.

Abstract:
The Architecture, Habitability & Integration group (AH&I) is a system engineering and integration test team within the NASA Crew and Thermal Systems Division (CTSD) at Johnson Space Center. AH&I identifies and resolves system-level integration issues within the research and technology development community. The timely resolution of these integration issues is fundamental to the development of human system requirements and exploration capability.

The integration of the many individual components necessary to construct an artificial environment is difficult. The necessary interactions between individual components and systems must be approached in a piece-wise fashion to achieve repeatable results. A formal systems engineering (SE) approach to define, develop, and integrate quality systems within the life support community has been developed. This approach will allow a Research & Technology Program to systematically approach the development, management, and quality of technology deliverables to the various exploration missions.

A tiered system engineering structure has been proposed to implement best systems engineering practices across all development levels from basic research to working assemblies. These practices will be implemented through a management plan across all applicable programs, projects, elements and teams.

While many of the engineering practices are common to other industries, the implementation is specific to technology development. An accounting of the systems engineering management philosophy will be discussed and the associated programmatic processes will be presented.

Biography:
Name: Kriss J. Kennedy, Space Architect
Title: Lead, Architecture, Habitability and Integration
Organization: NASA Johnson Space Center (JSC)
Voice: (281)-483-6629 Fax : (281) 483-2508 E-mail: kriss.j.kennedy@nasa.gov

Mr. Kennedy is a space architect at NASA and is responsible for leading teams performing systems engineering and integrated testing for technology development for exploration systems. His accomplishments over 18 years at NASA include leading many lunar and Mars spacecraft design teams, technology developments—such as TransHab, Inflatable Airlock, and Deployable Crew Quarters—ISS hardware development, and lead several SE&I activities—most recently the HSRT SE&I Systems Engineering Management Plan.

Prior to this position, Mr. Kennedy was the JSC Orbital Space Plane Project Office Vehicle Engineering Subsystem Manager and the safety representative for the Joint Software Review Board. Prior to his employment at JSC, he worked in the architectural industry for numerous architects around the country. Mr. Kennedy has several patents, numerous awards and over 40 publications and papers.

Mr. Kennedy is a licensed architect in Texas, holds a Masters of Architecture from the University of Houston and a Bachelor's degree from the University of Buffalo.

Systems Engineering & Integration for Technology Programs

Project Management Challenge Conference

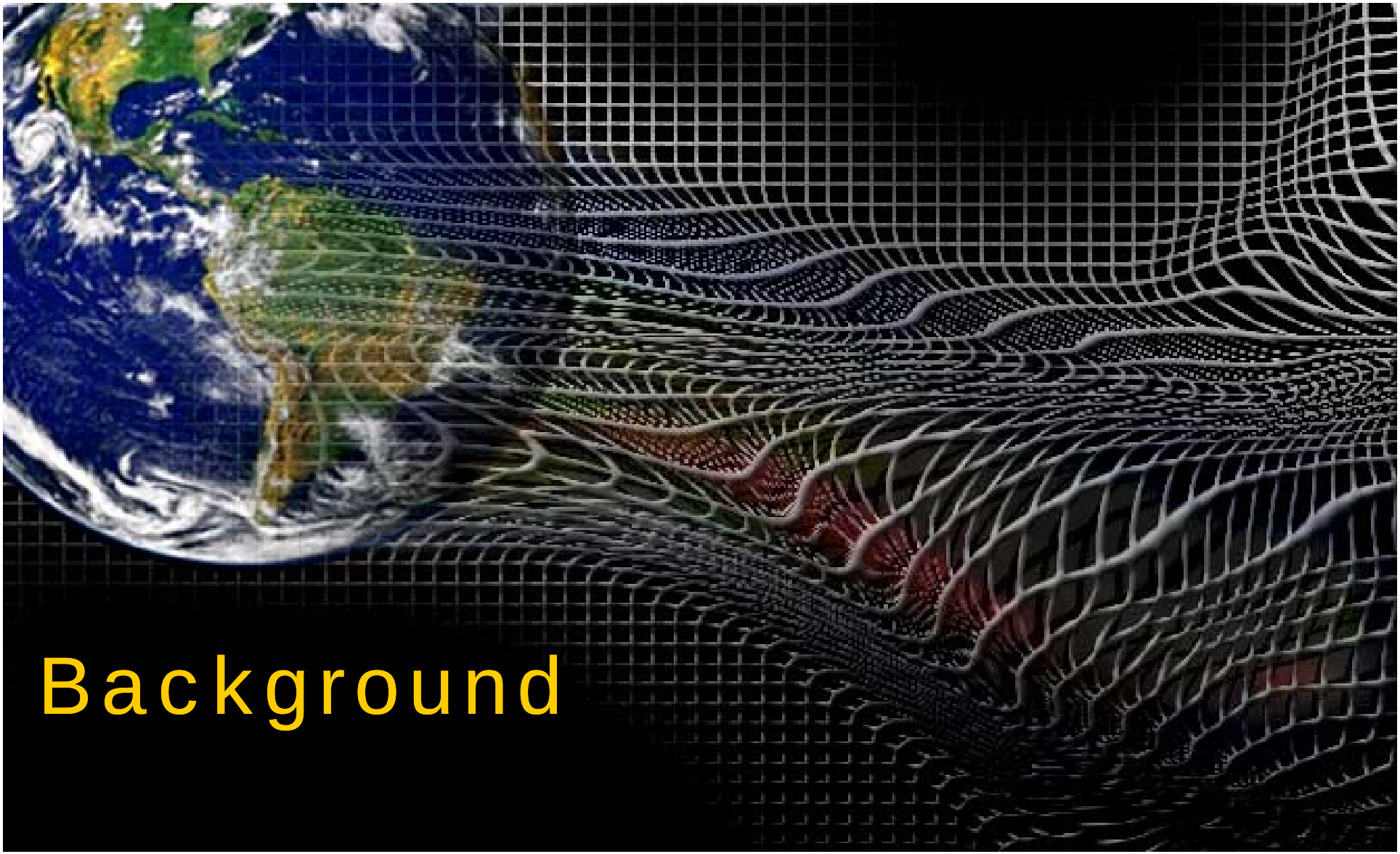
Galveston, Texas
March 21 & 22, 2006

Kriss J. Kennedy
Space Architect
NASA Johnson Space Center

Architecture
Habitation &
Integration

Agenda

- Background & Team
- Research & Technology Development
- Systems Management
- Systems Engineering
- Systems Analysis
- Systems Integration & Testing
- Summary



Background

HSRT SE&I Team

- Multi-Center SE Team
- ONE-NASA Approach
- SE&I must focus on: Processes, People, & Tools

Multi-Center SE Team (many folks with leads from 5 centers)

- Britt Walters / NASA JSC-HQ lead
- Mark Jernigan / NASA JSC-SA

Multi-Center SE Team

- Kriss Kennedy / NASA JSC lead
  - Molly Anderson
  - John Park
  - Ivan Cavenall
  - Paul Campbell
  - Debbie Berdich
  - Phil Landis
- Brad Perkins & Tim Smith / NASA MSFC leads
  - Howard Estes
  - Joe Lashley
- Richard Lauver / NASA GRC lead
- Harry Jones / NASA ARC lead
- Dan Shultz / NASA KSC lead

Background

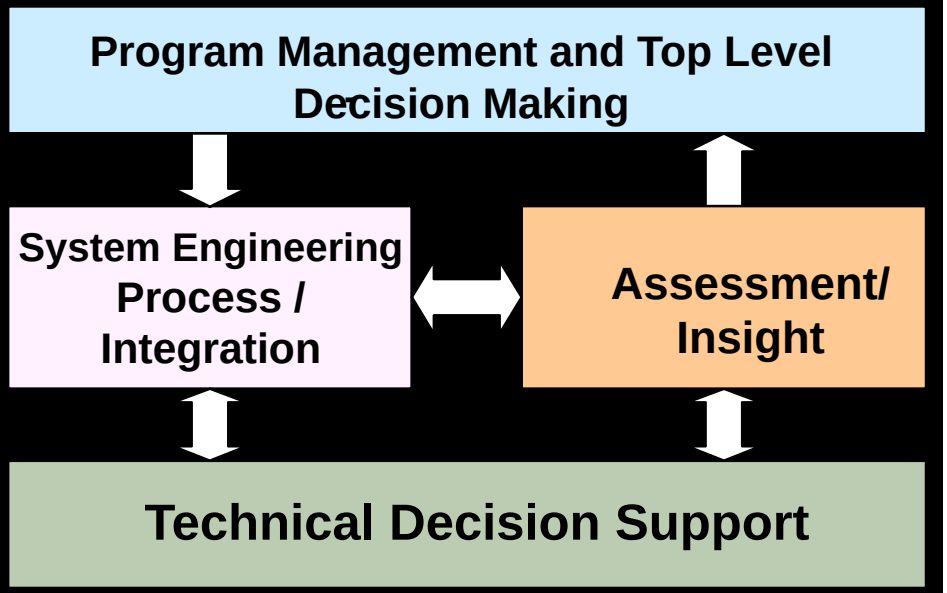
- SE&I processes herein based on work done for Systems Engineering Management Plan (SEMP) for the then Human Systems Research & Technology (HSRT) Program @ HQ, early FY05.
- This presentation will not cover all the aspects of the SE&I for Technology addressed by our SEMP team.

Focused on:

- Technology Life-Cycle Definition of the System Engineering Tier structure
- Annual review
- Programs and technology elements
- Infusion
- Tech integrated testing
- Transition and delivery
- Development of Concepts of Operations
- technical performance measurements & metrics
- Definition of requirements and flow-down.
- Configuration management for Tech products
- Risk management

SE&I Product-Oriented View

- Define Technology Products
  - Sync ESMD Milestones & Technology Gateways
- Define Technology Development Processes
  - Policy, Procedures, Standards, Tools, and Quality
- Define Organizations for Implementation
  - Align with Products & Processes

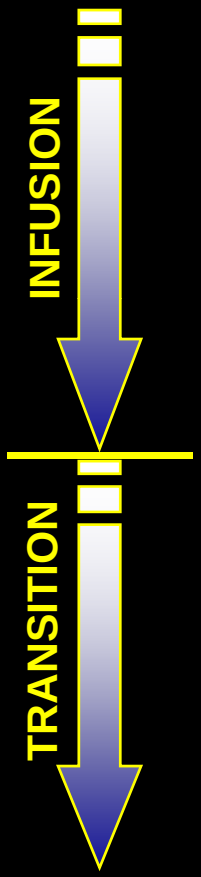


SE&I Processes for Technology Development

Infusion and Transition of Technologies

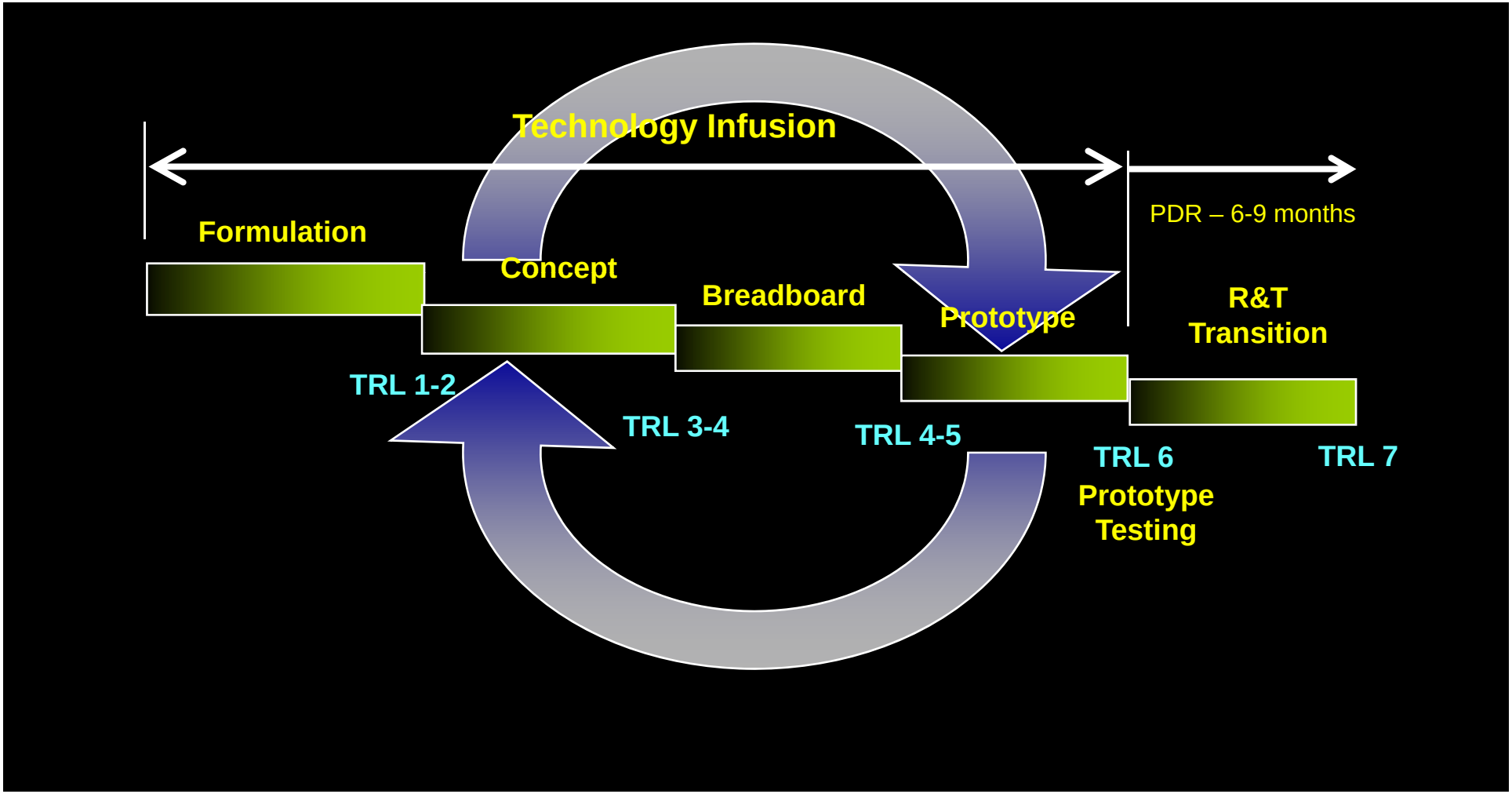
- Infusion is the technology integration with Constellation
- Technology transition includes :
  - validation and verification
  - the transition of Technology authority
  - continue support to reach flight hardware/software maturity.

Technology Readiness Levels Summary



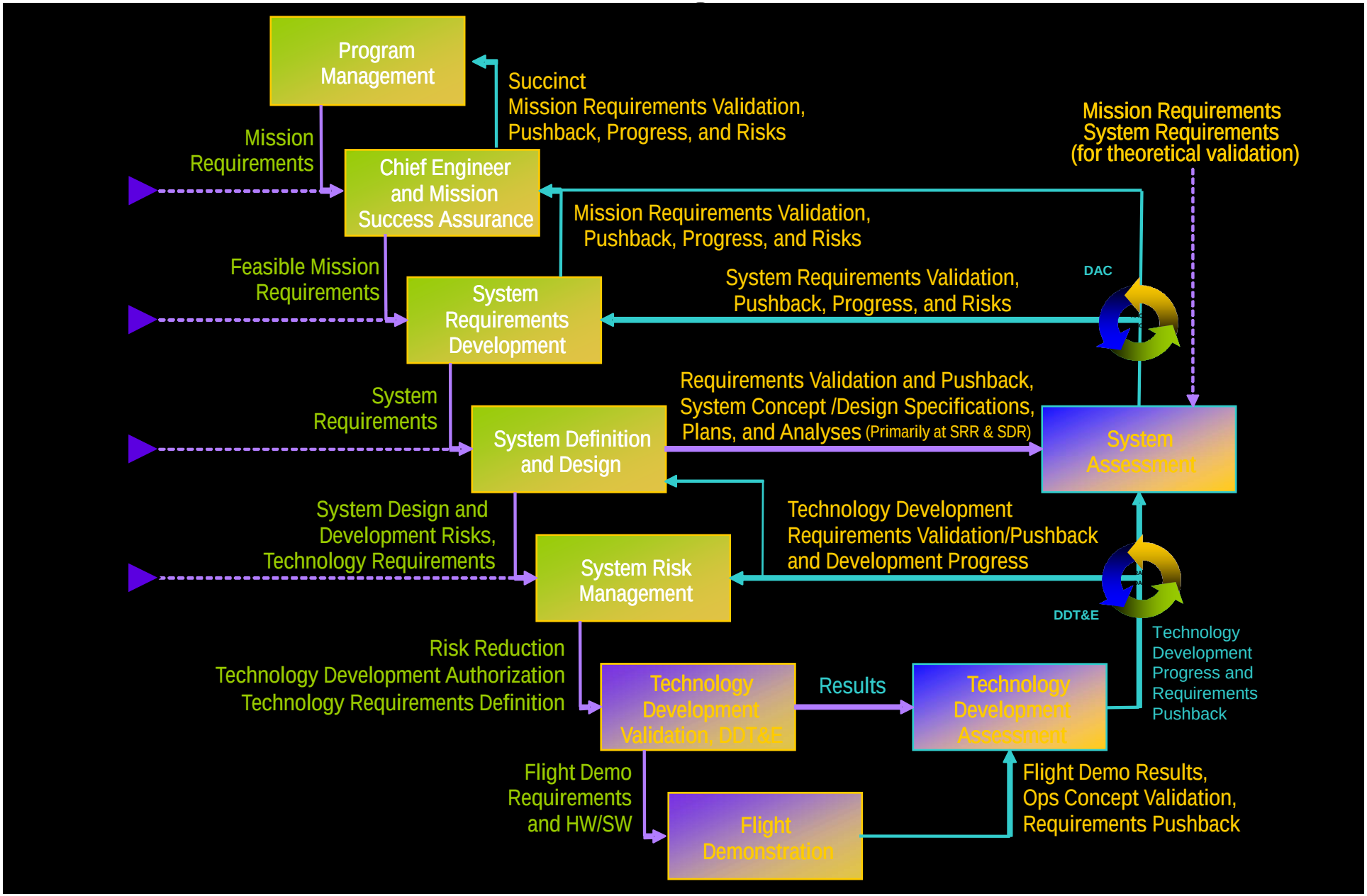
- TRL 1 Basic principles observed and reported
- TRL 2 Technology concept and/or application formulated
- TRL 3 Analytical and experimental critical function and/or characteristic proof-of concept
- TRL 4 Component and/or breadboard validation in laboratory environment
- TRL 5 Component and/or breadboard validation in relevant environment
- TRL 6 System/subsystem model or prototype demonstration in a relevant environment (ground or space)
- TRL 7 System prototype demonstration in a space environment
- TRL 8 Actual system completed and “flight qualified” through test and demonstration (ground or space)
- TRL 9 Actual system “flight proven” through successful mission operations

Technology Life-Cycle



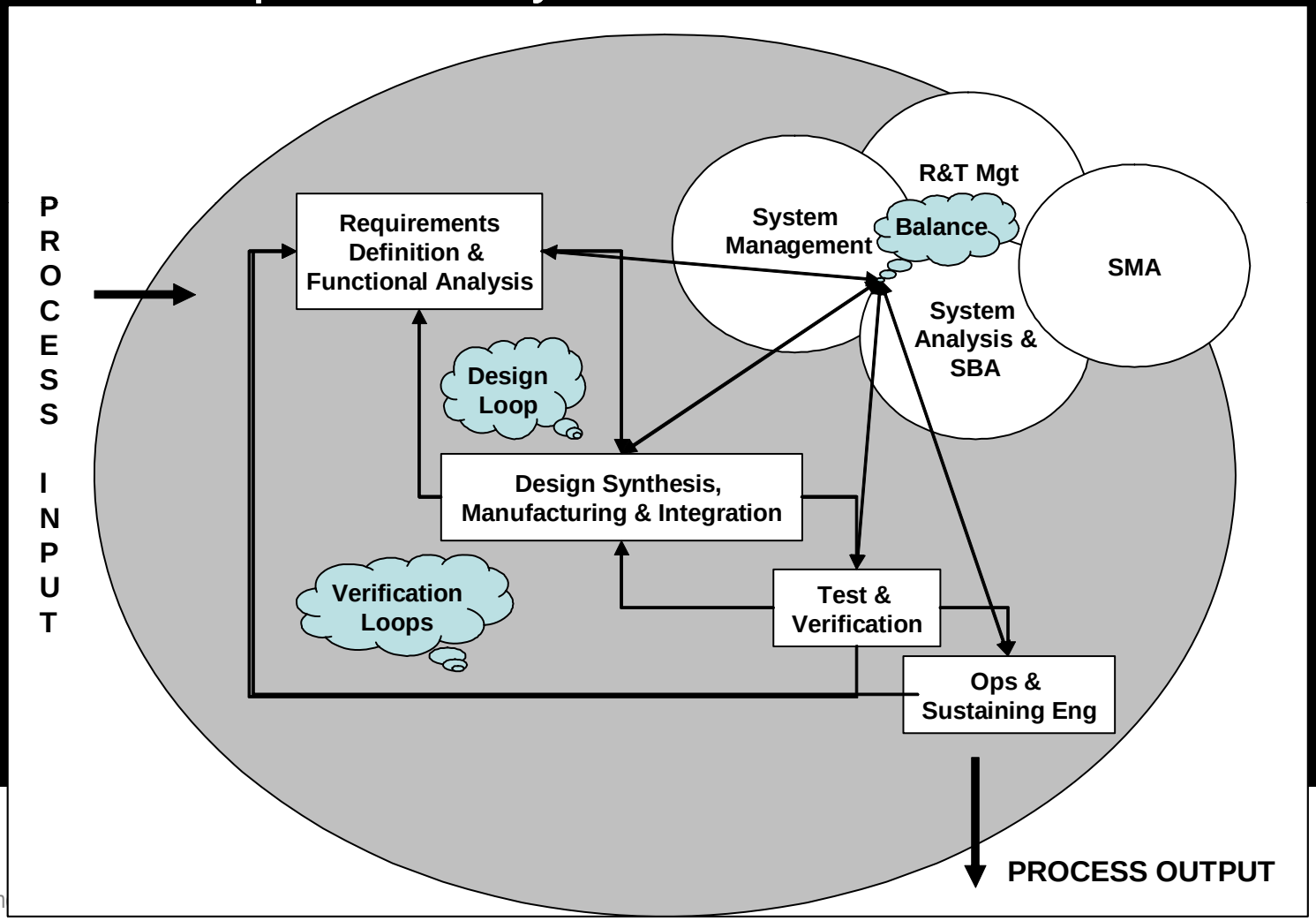
Technology Development Strategy

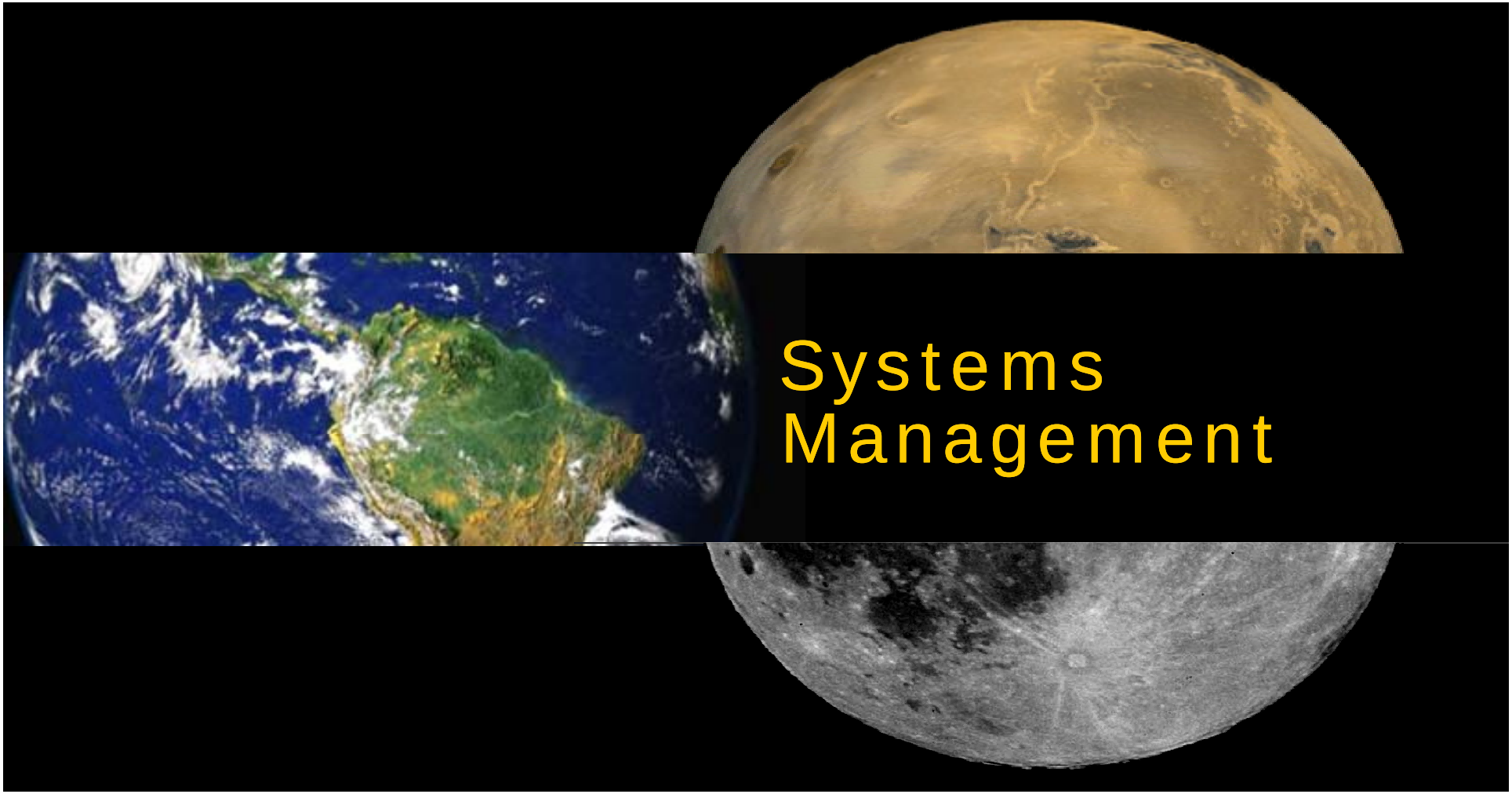
Technology SE&I



Top Level SE&I Process

R&T development life-cycle occurs within this framework.




Systems
Management

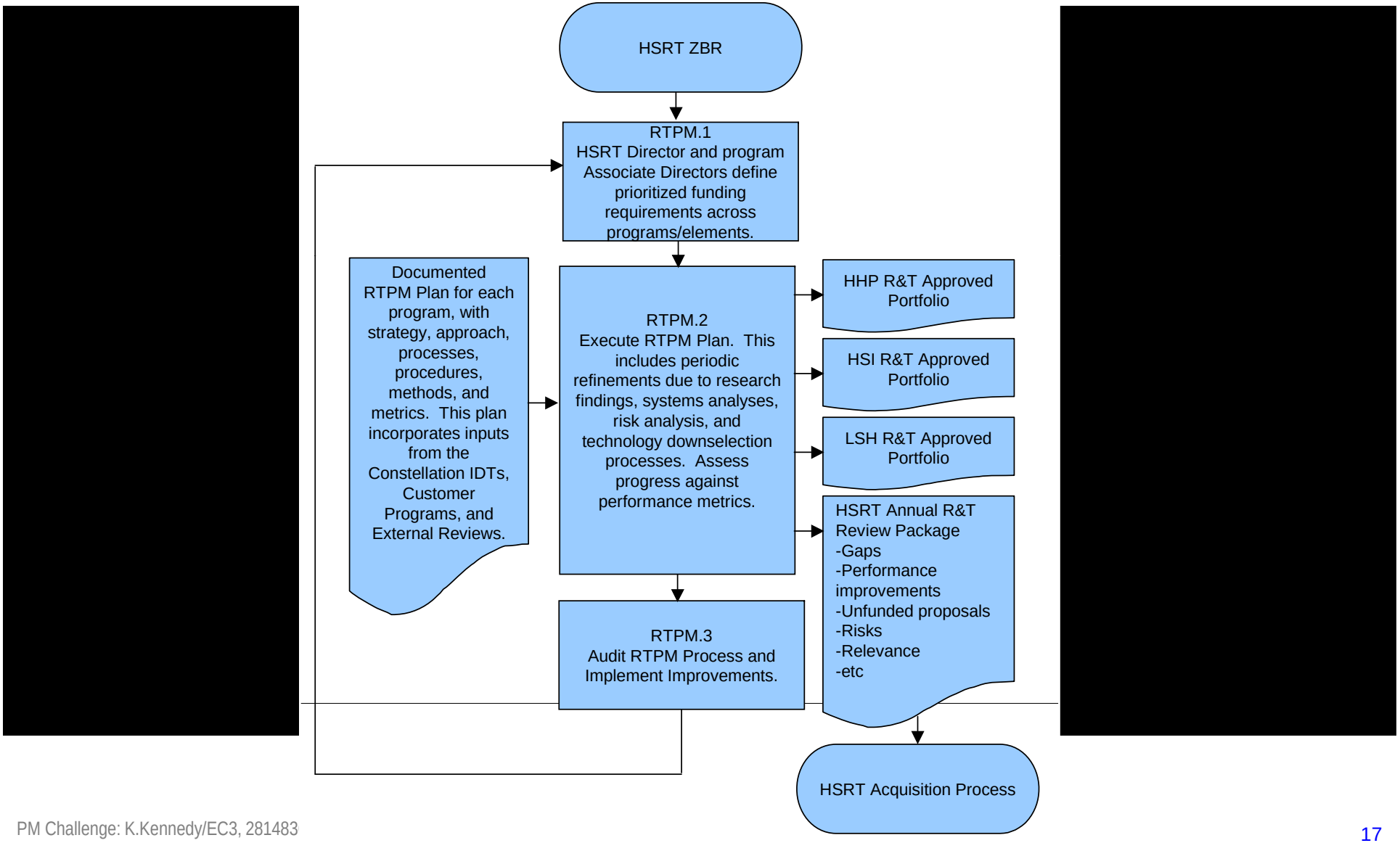
Systems Management

- System Management and Control
  - Planning, Monitoring, and Control
  - Reporting and Reviews
  - Configuration and Data Management
  - Risk Management

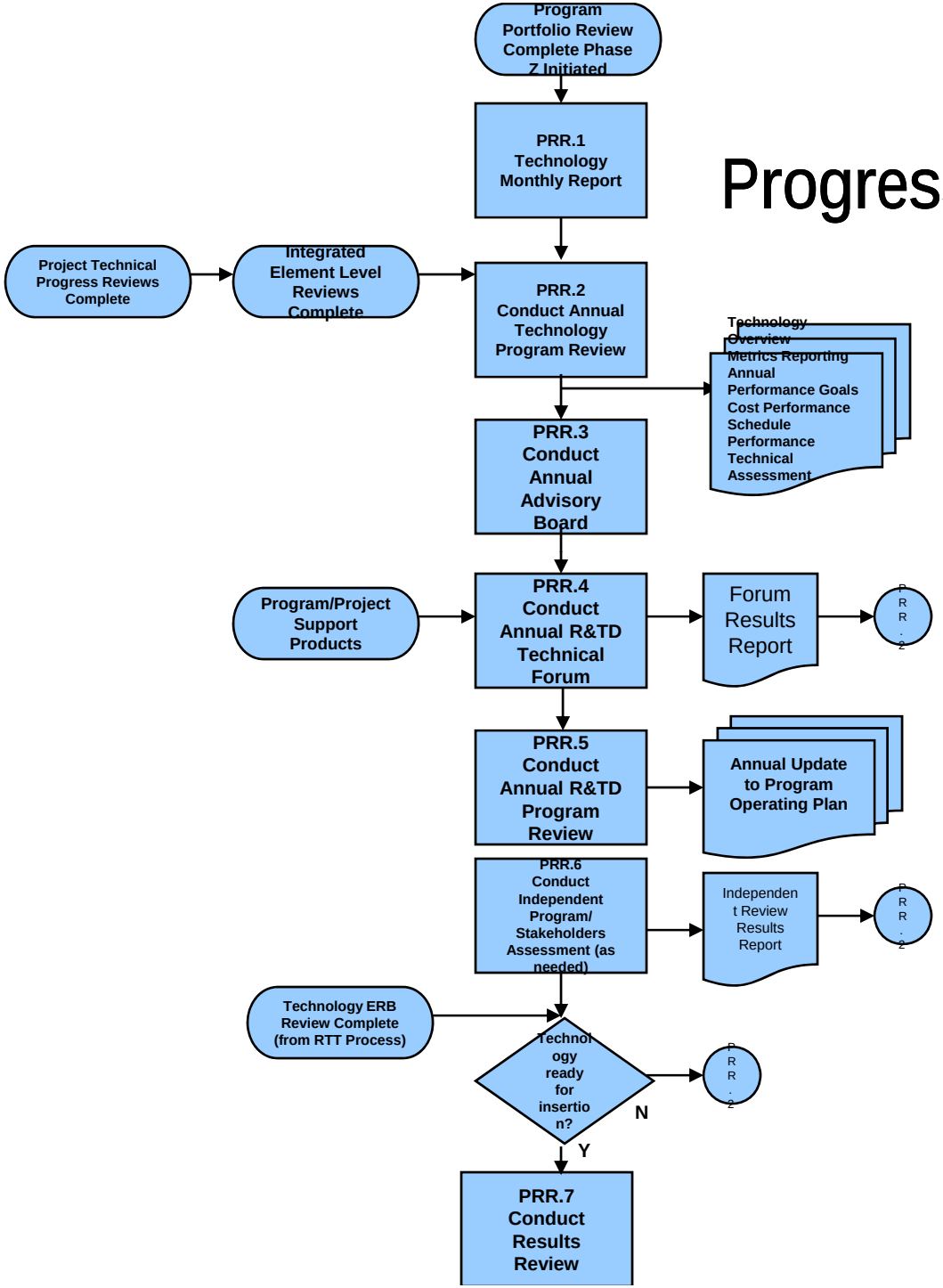
Establish SE Roles and Responsibilities

- Establish Criteria for system-level trade studies, assessments, and testing
- Maintain baseline requirements
- Manage requirements flows and allocations
- Provide method to obtain evaluations from subject matter experts for change requests or concept of operations.
- Maintain all SEMP processes
- Integrate Tech portfolios
- Integrate Risk Management
- Coordinate with ESMD and Constellation
- Coordinate membership and support to other forums
- Establish Program Reviews schedule and content
- Conduct technical audits
- Logistics for review of Programs
  - entrance & exit criteria
- Develop requirements for infrastructure
- Establish and maintain document tree
- Liaison to other systems engineering organizations
- Establish system-level criteria for transition of technology deliverables

Technology Portfolio Assessments Process



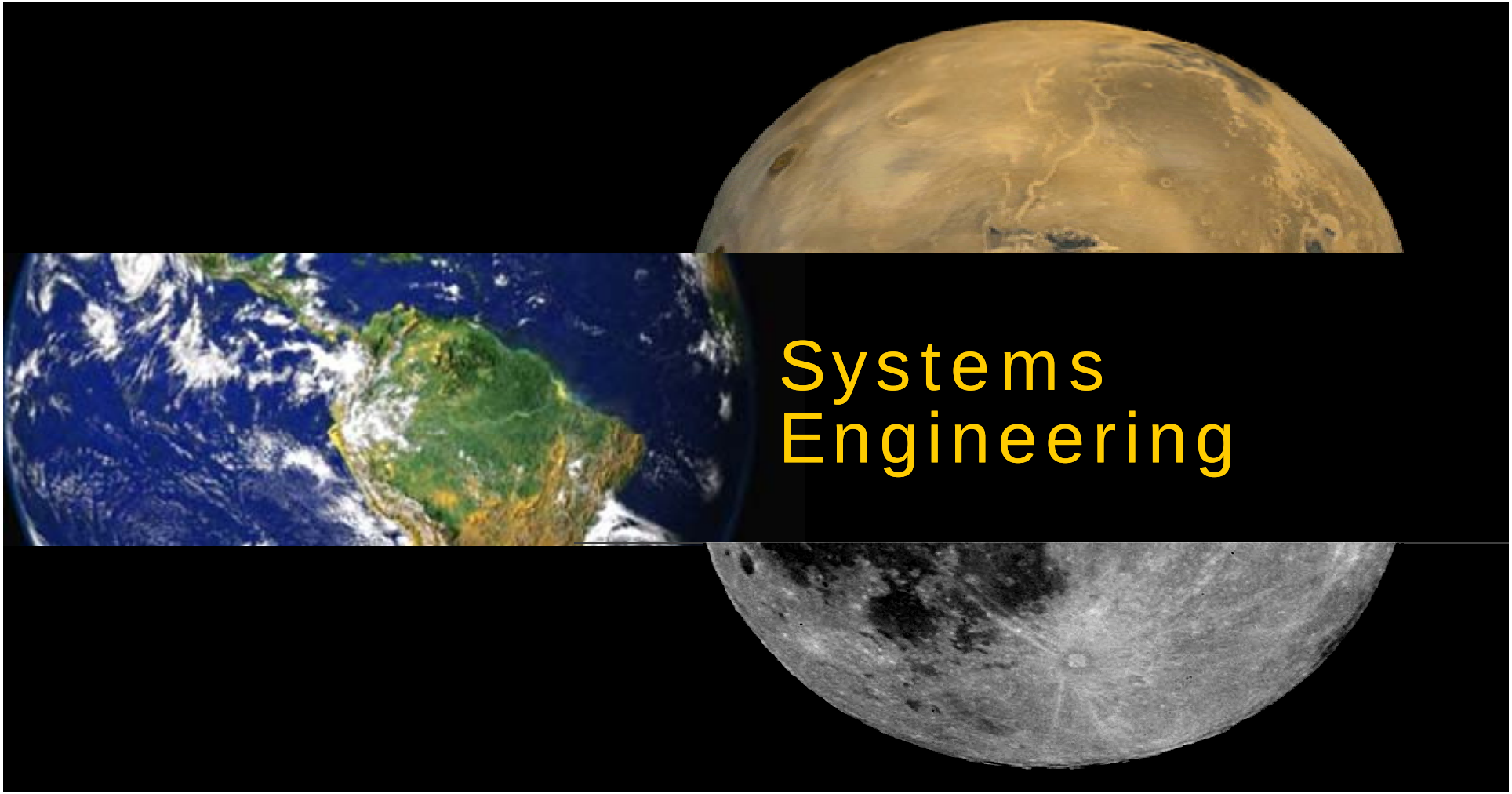
Progress Reporting



Risk Management

Continuous Risk Management (CRM) will be included as part of the Technology Program system control process to accomplish the following objectives:

- Identify the potential sources of risk and identify the risk drivers.
- Quantify risks and assess their impacts on cost, schedule, and performance.
- Determine the sensitivity of these risks to program, product and process assumptions, and the degree of correlation among the risks.
- Determine and evaluate alternative approaches to mitigate high risks.
- Take actions to avoid, control, accept, or transfer each risk.
- Ensure that risk is traded-off in decisions on specification requirements and solution alternatives.
- The Technology Program and each of its elements and projects will conduct CRM in accordance with NPR 7120.5 and NPR 8000.4.

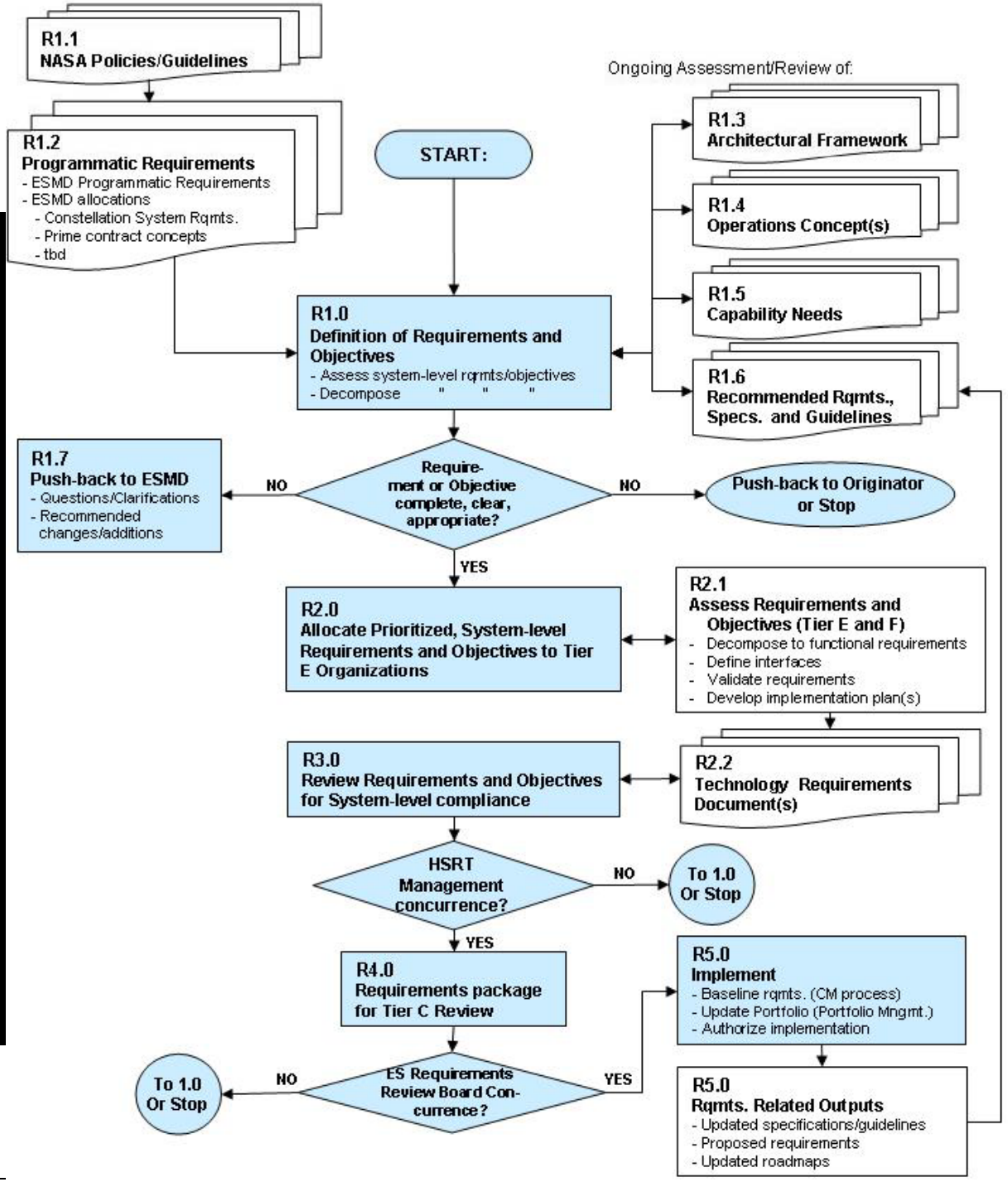

Systems
Engineering

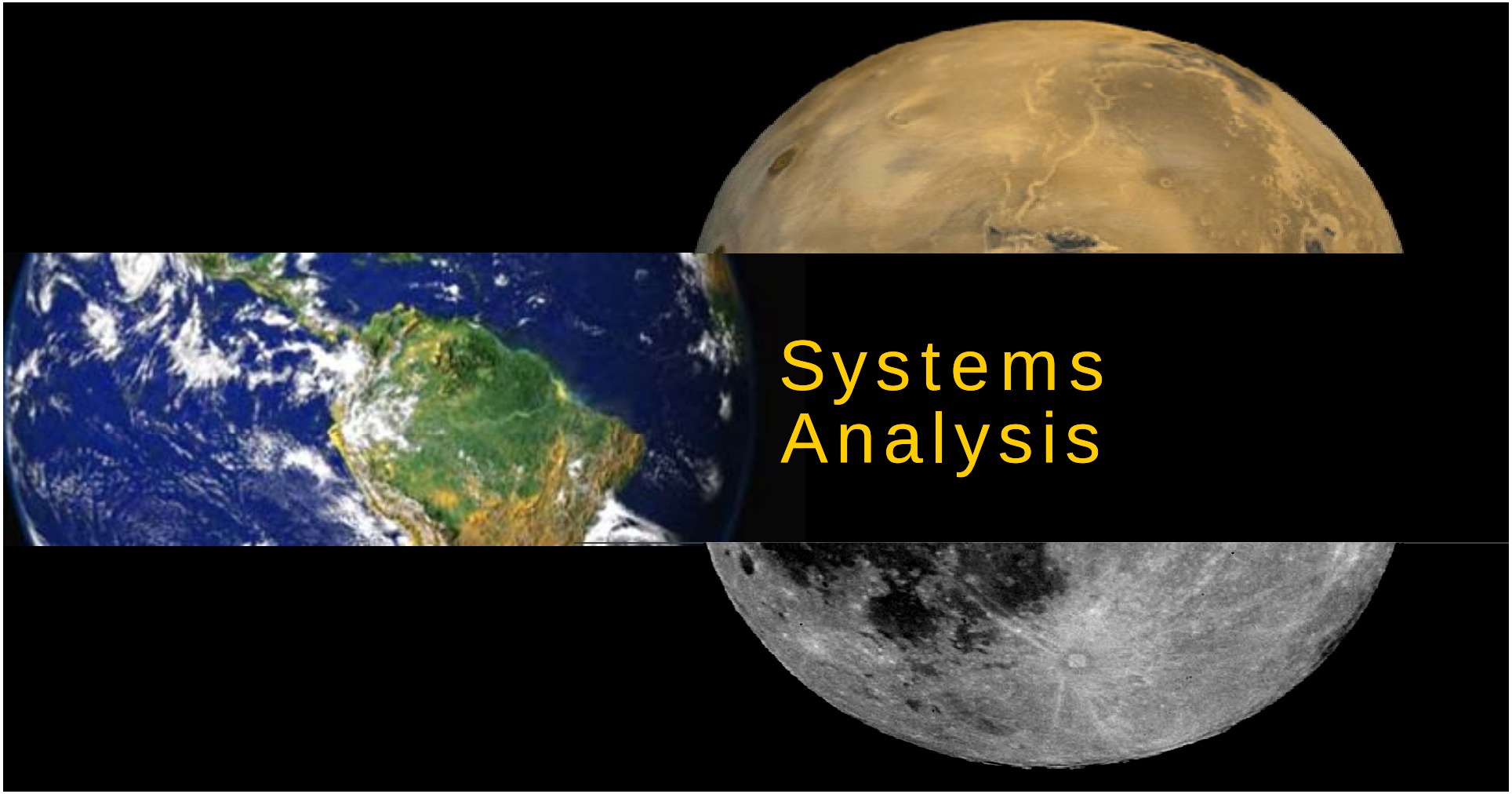
Systems Engineering

- Requirements Development
  - Requirements traceability and Decomposition to Research & Technology Projects
    - Requirements Assessment, Allocation, and Detailed Functional Decomposition
    - Functional Decomposition
    - Development of Performance Requirements for Allocated Functions
  - Documentation

Requirements Development

- Requirements Traceability and Decomposition to Research & Technology Projects
- Requirements Assessment, Allocation, and Detailed Functional Decomposition
- Functional Decomposition
- Development of Performance Requirements for Allocated Functions
- Documentation
- Review and Approval



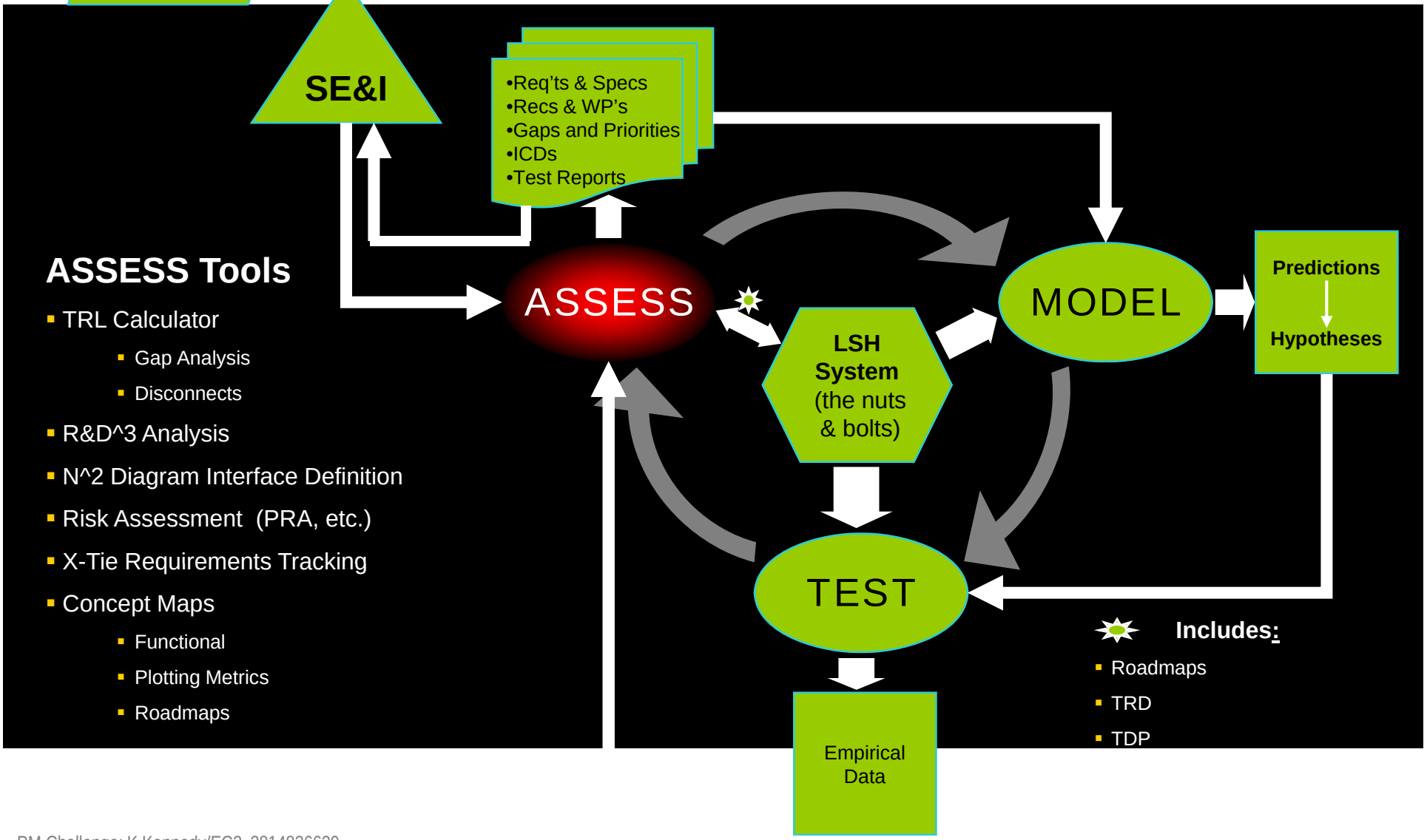

Systems
Analysis

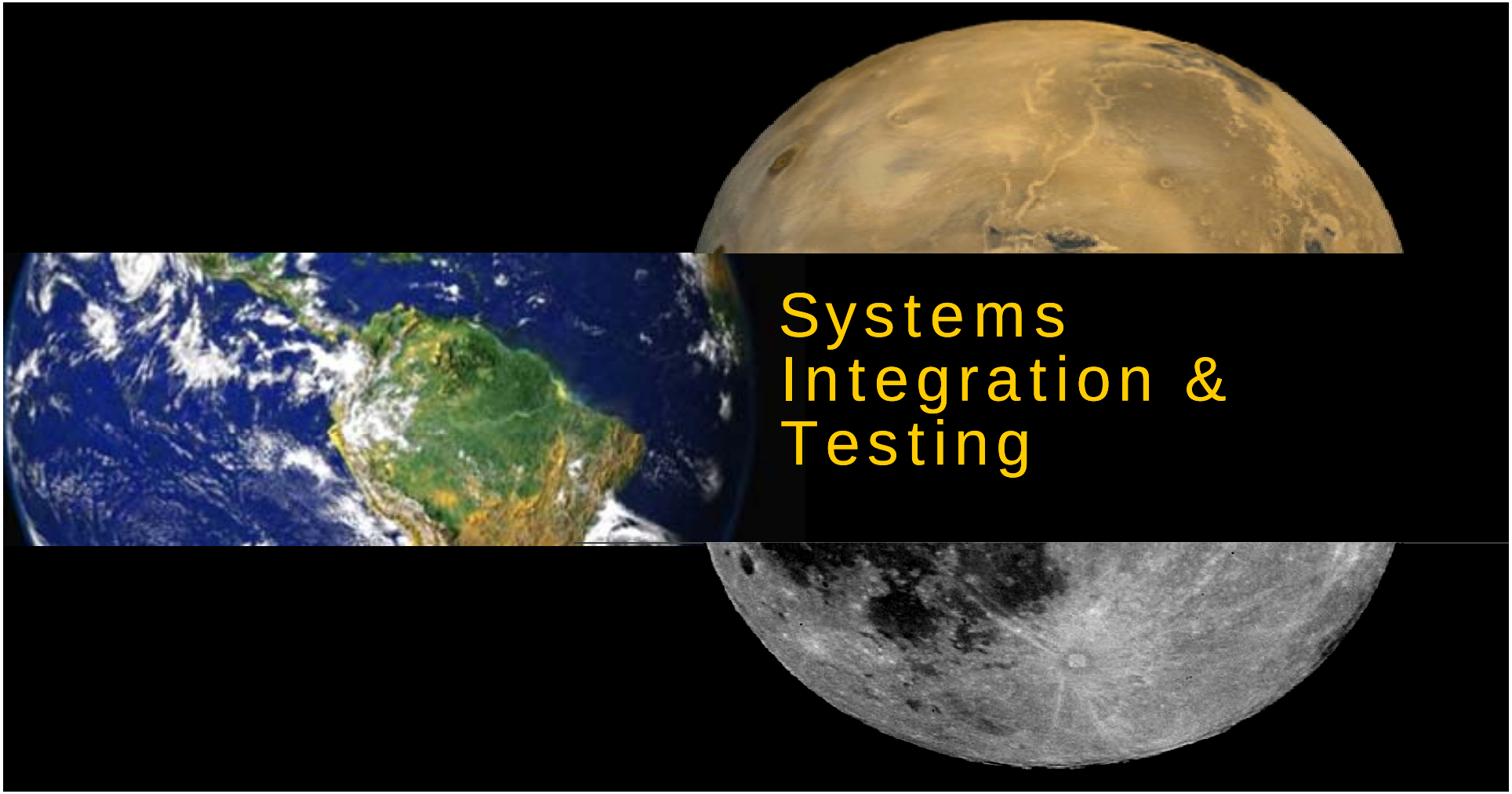
Systems Analysis & Modeling

- Requirements Gap Analysis and Validation
- Architecture Design and Validation
- Systems Analysis in Research and Technology Portfolio Management
- Inputs to Strategy to Task to Technology and Simulation Based Acquisition
- System Analysis Tools

A Systems Analysis Process
For Technology Integration & Development

Constellation
- **DRM**
- **Requirements**
- **Architecture**



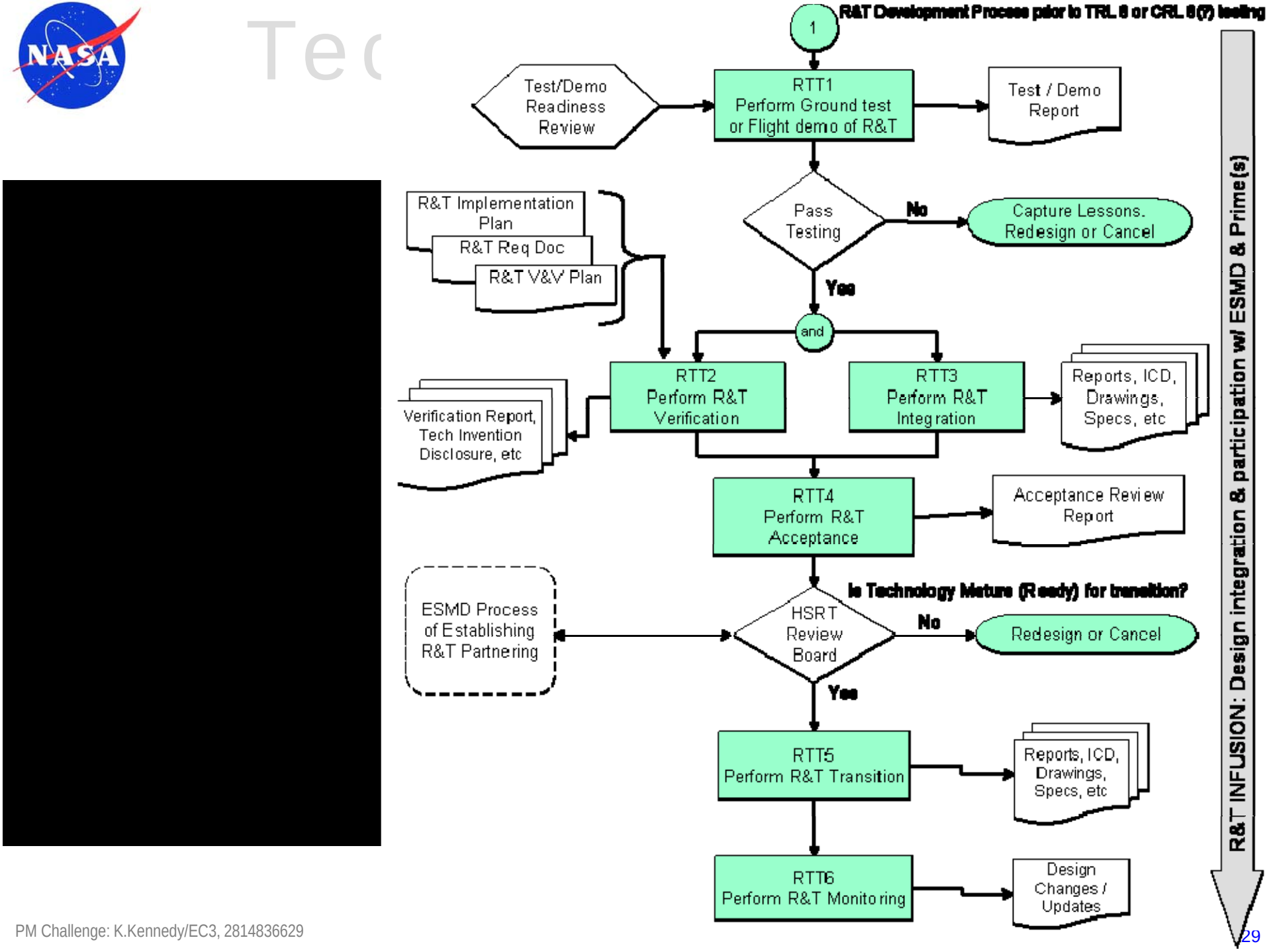

Systems
Integration &
Testing

Design Synthesis, Manufacturing and Assembly

- Design
  - Design Participation of Constellation Vehicle's) DDT&E
  - Interface design for infusion of technology
  - Reliability, Maintainability, and Supportability (RMS)
- Manufacturing
  - Prototypes and Flight Test
  - Concept of Operations evaluation
  - Reliability/Usability studies
  - Verification

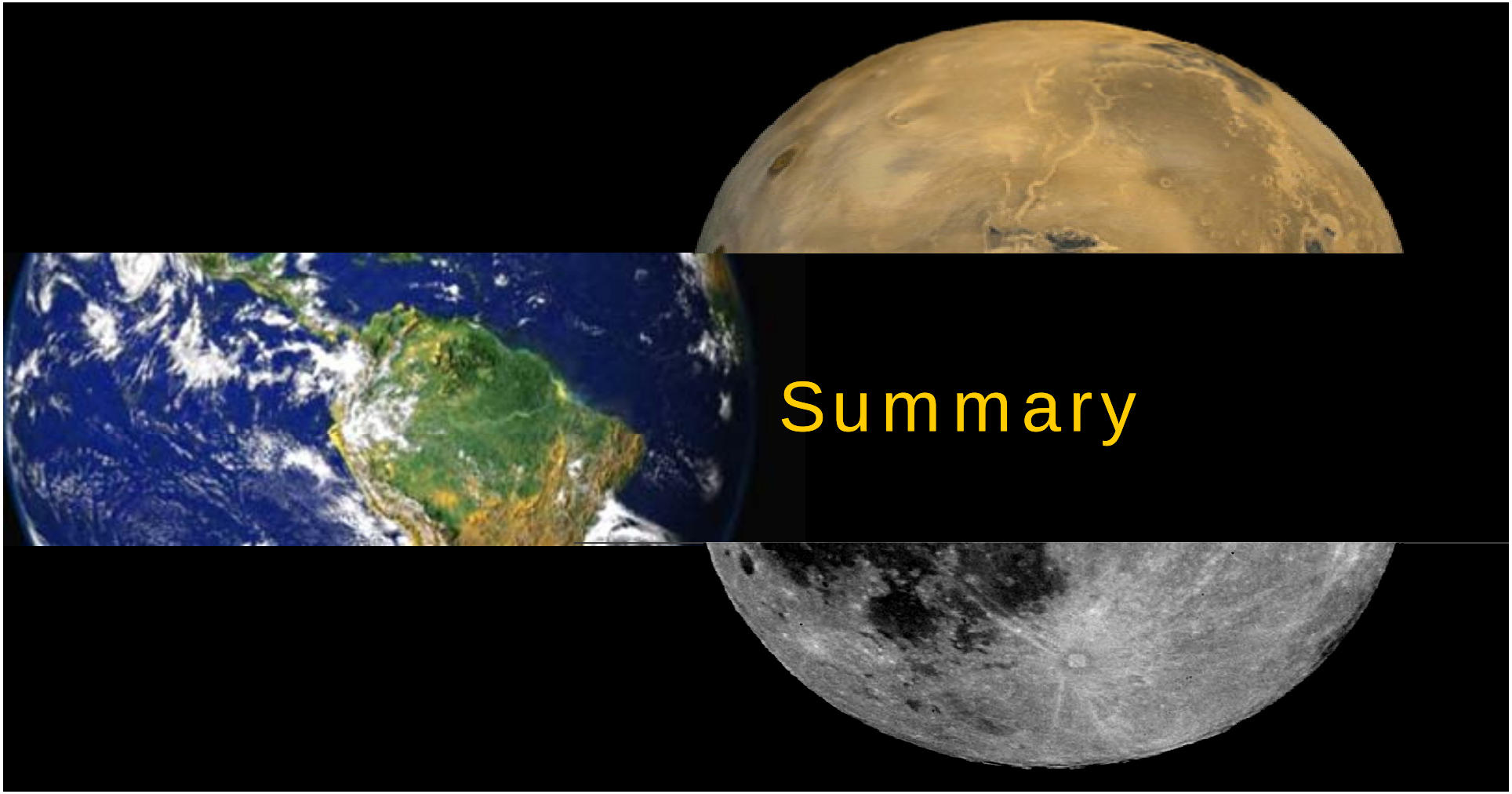
Systems Integration

- R&T Integrated Test and Evaluation
  - Evaluation of Prototypes
  - Integrated Testing
  - Evaluation of test data
  - Management of technical performance measurements


R&T Development Process prior to TRL 6 or CRL 6(7) testing
1
Test/Demo Readiness Review
RTT1 Perform Ground test or Flight demo of R&T
Test / Demo Report
R&T Implementation Plan
R&T Req Doc
R&T V&V Plan
Pass Testing
No
Capture Lessons. Redesign or Cancel
Yes
and
RTT2 Perform R&T Verification
RTT3 Perform R&T Integration
Verification Report, Tech Invention Disclosure, etc
Reports, ICD, Drawings, Specs, etc
RTT4 Perform R&T Acceptance
Acceptance Review Report
ESMD Process of Establishing R&T Partnering
Is Technology Mature (Ready) for transition?
HSRT Review Board
No
Redesign or Cancel
Yes
RTT5 Perform R&T Transition
Reports, ICD, Drawings, Specs, etc
RTT6 Perform R&T Monitoring
Design Changes / Updates
R&T INFUSION: Design integration & participation w/ ESMD & Prime(s)

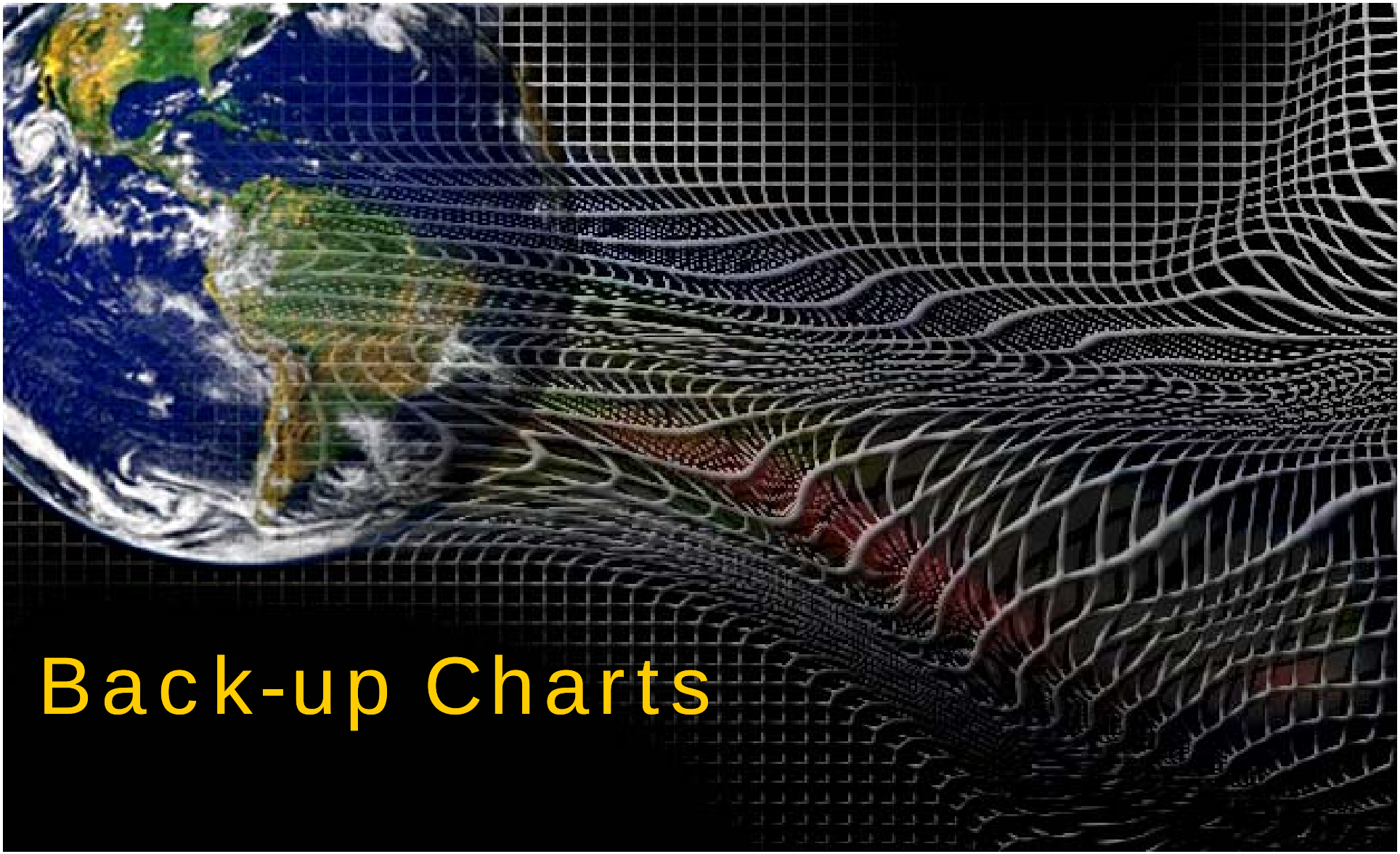
Operations and Sustaining Engineering

- Operations and Sustaining Engineering
  - Human Systems operational parameter monitoring
  - Research and Technology Sustaining Engineering


Summary

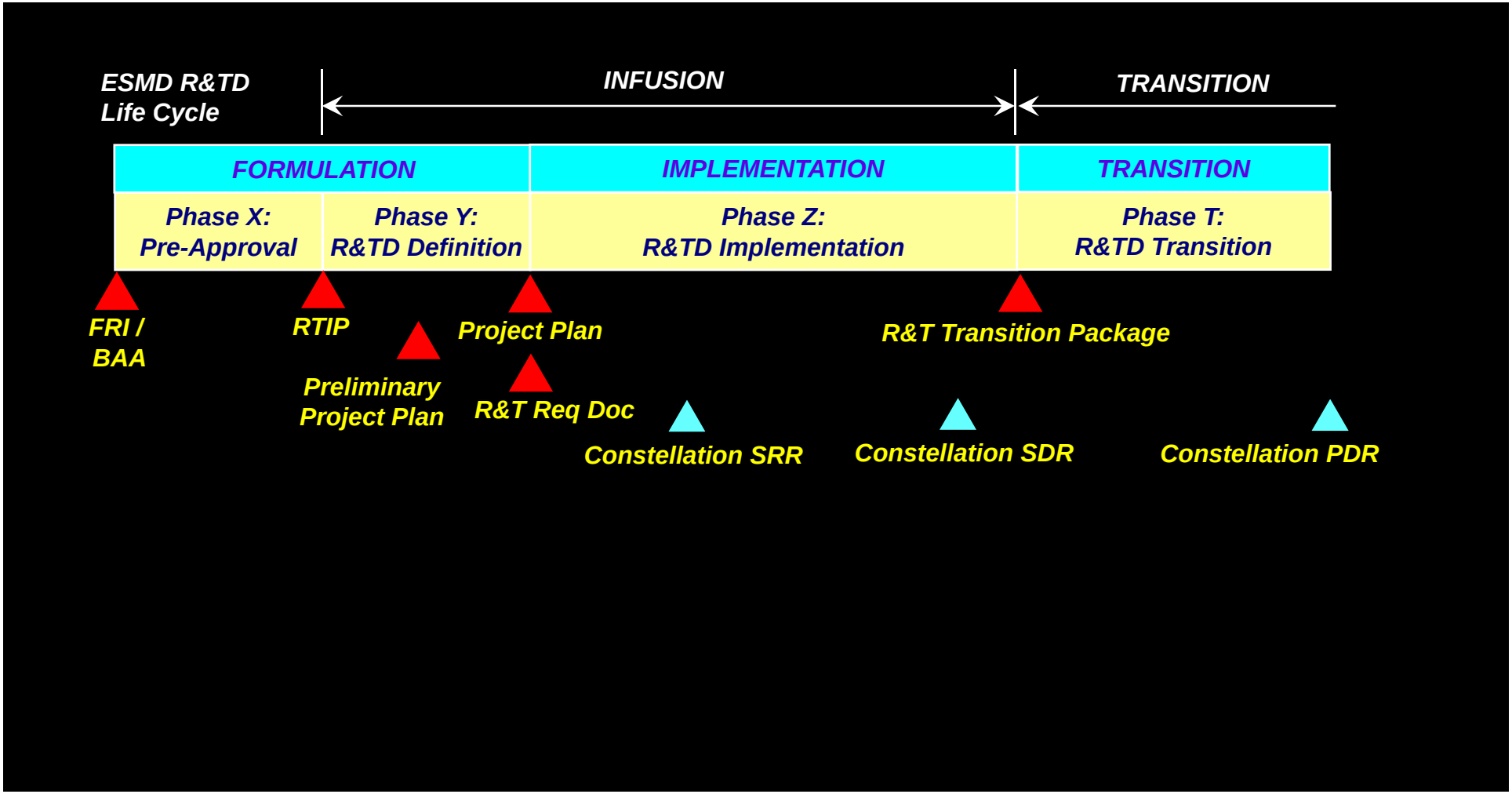
Summary

- Technology Develop needs consistent
  - Processes
  - Products @ TRL
  - Infusion & Transition to Vehicle Developers
  - Integrated Testing
  - Early Mitigation of Integration Issues



Back-up Charts

Technology Phases



SE Hierarchy

A Hierarchical System Terminology

The following hierarchical sequence of terms for successively finer resolution was adopted by the NASA -wide Systems Engineering Working Group (SEWG) and its successor, the Systems Engineering Process Improvement Task (SEPIT) team:

System
Segment
Element
Subsystem
Assembly
Subassembly
Part

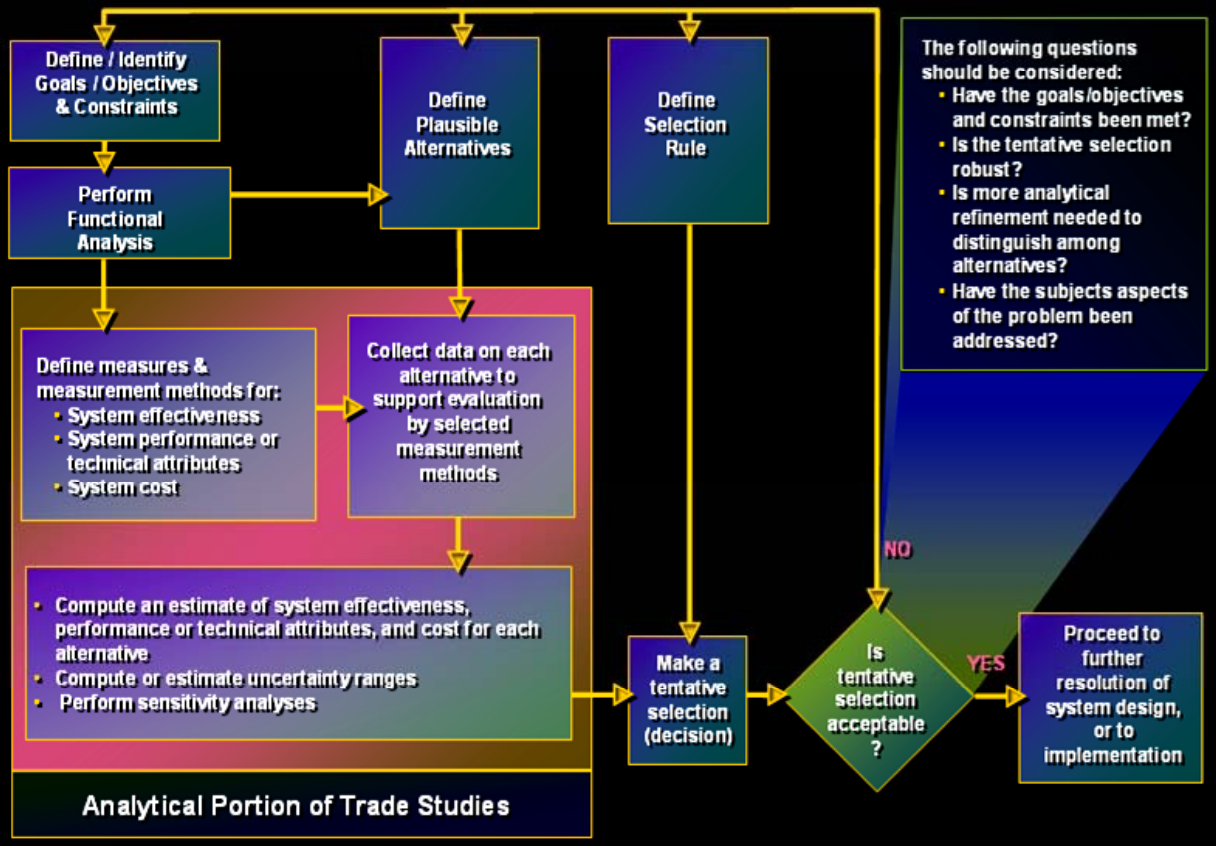
Particular projects may need a different sequence of layers— an instrument may not need as many layers, while a broad initiative may need to distinguish more layers. Projects should establish their own terminology. The word *system* is also used within NASA generically, as defined in the text. In this handbook, "system" is generally used in its generic form.

NASA Systems Engineering Handbook, SP-6105, June 1995

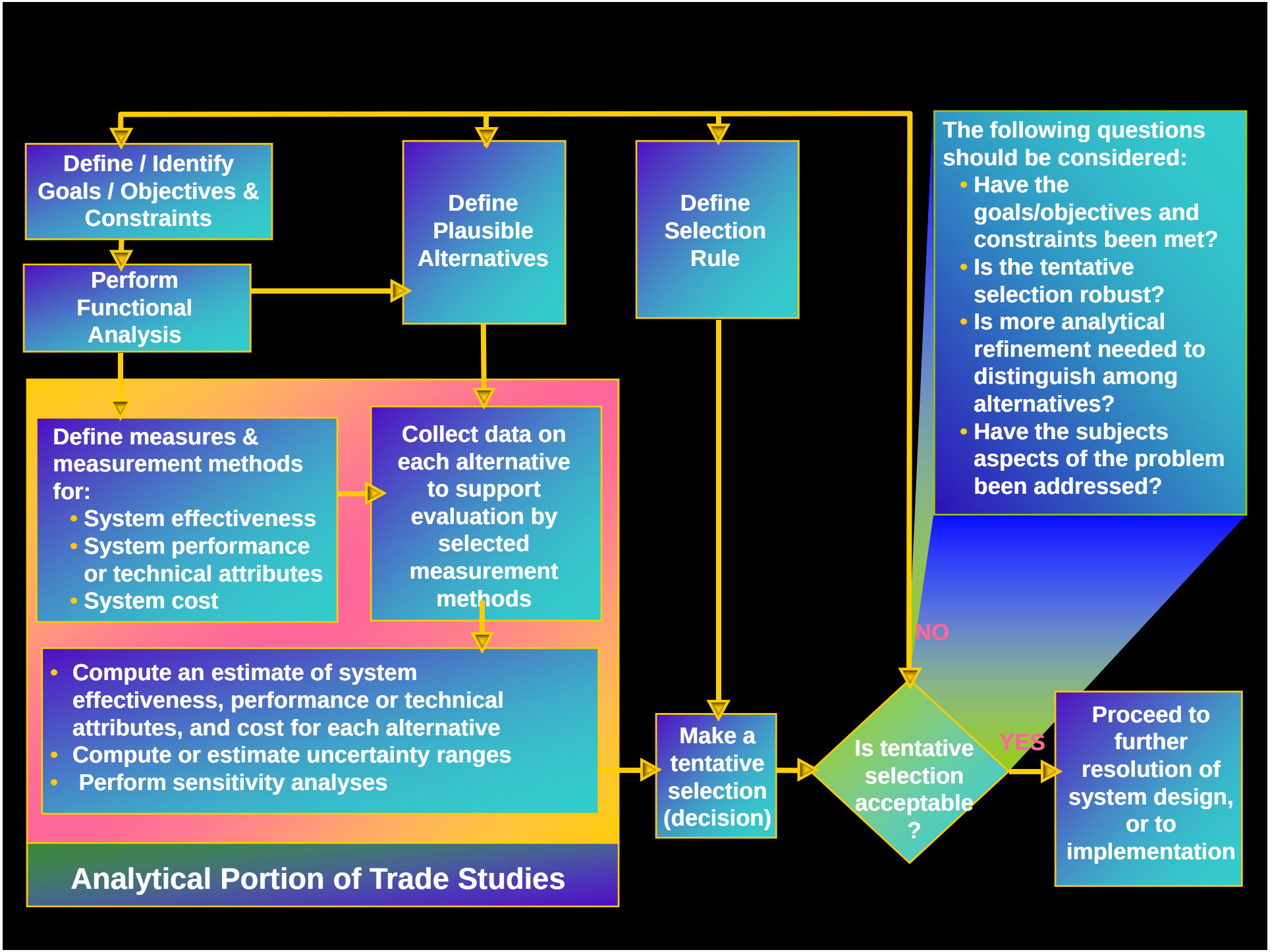
Trade Study Reports

- Trade study reports should be prepared for each trade study. At a minimum, each trade study report should identify:
  - The system issue under analysis
  - System goals and objectives (or requirements, as appropriate to the level of resolution), and constraints
  - The measures and measurement methods (models) used
  - All data sources used
  - The alternatives chosen for analysis
  - The computational results, including uncertainty ranges and sensitivity analyses performed
  - The selection rule used
  - The recommended alternative.
- Trade study reports should be maintained as part of the system archives so as to ensure traceability of decisions made through the systems engineering process. Using a generally consistent format for these reports also makes it easier to review and assimilate them into the formal change control process.

Trade Study Process



NASA Systems Engineering Handbook, SP-6105, June 1995


Define / Identify Goals / Objectives & Constraints
Perform Functional Analysis
Define Plausible Alternatives
Define Selection Rule
Define measures & measurement methods for:
• System effectiveness
• System performance or technical attributes
• System cost
Collect data on each alternative to support evaluation by selected measurement methods
• Compute an estimate of system effectiveness, performance or technical attributes, and cost for each alternative
• Compute or estimate uncertainty ranges
• Perform sensitivity analyses
Analytical Portion of Trade Studies
Make a tentative selection (decision)
Is tentative selection acceptable ?
NO
YES
Proceed to further resolution of system design, or to implementation
The following questions should be considered:
• Have the goals/objectives and constraints been met?
• Is the tentative selection robust?
• Is more analytical refinement needed to distinguish among alternatives?
• Have the subjects aspects of the problem been addressed?

Systems Engineering References

- NASA Systems Engineering Handbook, SP6015,June 1995
- Systems Engineering Handbook, v2, July 2000, International Council on Systems Engineering
- IEEE Standard for Application and Management of the Systems Engineering Process, IEEE Std 1220-1998, Institute of Electrical and Electronics Engineers
- Patterns of Product Development Interactions; Steven D. Eppinger, MIT, 2001
- Manager's Guide to Technology Transition in an Evolutionary Acquisition Environment, v1, Jan. 2003, Defense Procurement and Acquisition Policy Office of the Under Secretary of Defense (Acquisition, Technology and Logistics)
- Integrated Project Management Handbook: Interoperability/Systems Engineering And Acquisition Resource & Analysis/Acquisition Management; February 2002; Office of the Undersecretary of Defense, Acquisition Technology and Logistics
- DoD Space System Acquisition Process; #03-01; July 2004; National Security Space Acquisition Policy
- Joint Advanced Strike Technology Program: Strategy to Task to Technology Analysis; July 1995
- DoD Instruction 5000.2, "Operation of the Defense Acquisition System," May 2003